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THE GEOTECHNICAL SCIENCE LABORATORIES

Carleton University, Ottawa, Canada
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Geotechnical Science Laboratories 1971-1983

Some of the Geotechnical Science Laboratories group get together for an informal meeting at Carleton. Standing, left to right: Michael Smith (geography), Fred Michel (geology), Tom Wilkinson (geography), and Pete Johnson (geography). Seated: Alan Pendlington and Peter Williams (geography), Janet Wilson (secretary), and William Bowes (engineering).

The Geotechnical Science Laboratories began in 1971 with an understanding between five members of the Department of Geography that their research efforts would be worthy of more interest and support if they worked co-operatively. The common thread was an interest in the natural conditions and forms of the earth's surface. Arrangements were quite informal for many years; an annual list of publications and reports was almost the only visible collective activity apart from the research itself. However, grant funding and research contracts grew, and a part-time research administrator was appointed in 1973.

In spite of various constraints within and outside the University in the interim, from 1979 onwards there was a rapid increase in annual funding (now, a six-figure sum from external sources), in scope of projects, and in people involved. Some 25 researchers, graduate students, faculty and visiting scientists are associated with the laboratories' projects each year. With recognition in recent years of the role of various research units at Carleton, the laboratories have gained a firmer administrative and financial basis. This allows initiatives towards maintaining a high level of activity in the unit with the attendant financial advantages to the University. Pete Stanley, the geography department's administrator, carries a heavy work load for the laboratories.

Most important, the faculty and graduate students associated with the laboratories experience the stimulation of exciting, multi-faceted research which is of importance beyond the academic walls.

What is Geotechnical Science?

Most people think they know what "geography" is, although consensus is hard to reach. Even geographers are prone to say merely that "it's what they do." This catholicity of the subject meant the geotechnical science group developed an "outward," interdisciplinary approach. They study the surface of the earth (often on a small even microscopic scale), the substances it is composed of, and how they behave. This is the "science" in "Geotechnical Science." The "geotechnical" refers to the application of the study of the earth's surfaces to man and his activities, to engineering, to agriculture, and to environmental conservation. For example, dangerous stresses in big pipelines caused by permafrost; scratching of the seabed by glaciers; landslides; the effects of land drainage; frost-formed potholes in roads; and even the currently topical effects of change of climate, are all matters which have been studied in the laboratories. Often these practical concerns hide scientific problems frequently fascinating and always complex. To penetrate the complexity of these problems, scientists require a knowledge of such things as glaciers, blowing dust, sediments in streams, and the dispersal of the sun's energy at the ground surface.

Geotechnical engineering has to do with foundation design and construction of buildings, highways, bridges, as well as other features involving the ground. The geotechnical scientist does not usually design or build, but instead seeks knowledge of an often basic, but complex kind, to assist others in technological fields.

The projects in the laboratories involve the participation of engineers, geologists and others. The continuing association of the geography department and other disciplines is particularly valuable when problems of social and environmental impact are considered. Too often the scientific specialist is isolated from those in other fields concerned with the development and effects of modern science and technology.

Graduate students working in the Carleton Geotechnical Science Laboratories (which have no direct responsibility for academic programs) are registered in various departments with the majority in geography (the first Ph.D. thesis which eminated from the laboratories was that of an engineer in 1975). Recently, the Geotechnical Science Laboratories have become affiliated with the newly-established Ottawa-Carleton Centre for Geoscience Studies. The successes over the years and the developments that have occurred, not least because of inter-disciplinary links, suggest that research under the name of the Geotechnical Science Laboratories has indeed been appropriate for the times and for Carleton.

Present and Future

Three activities: the distribution of publications and reports; the holding of special seminars and mini-courses for professionals; and the establishment of foreign exchange through visits and visitors have been especially emphasized. Such outwardly-directed activities are one measure of the value of the research.

These activities are only worthwhile if imaginative and important research continues to be carried out at a high standard. There are many projects possible for the future, beyond those illustrated in this publication: Carleton geotechnical scientists could, for example, examine the problem of droughts which modify the ground surface and in turn promote adverse effects. To reverse these effects requires a broad and detailed knowledge of the soil, its vegetation, and of the atmosphere near the ground. Long before change of climate produces sensational effects there will be an agroclimatic problem in Canada, in which soil and climate give unfavourable wheat-growing conditions. Acid rain or carbon dioxide emissions are unlikely to be the last anthropogenic wrenches in the primitive machinery that passes for our understanding of that thin layer in which we live at the base of the atmosphere and at the surface of the earth.

To be in a position to meet such problems requires a close study of the nature and behaviour of soils and rocks at the earth's surface, and of the energy and mass flows between ground and atmosphere. A background in basic sciences, physics, chemistry and mathematics is essential, but one of the pleasures lies in applying such knowledge to the natural conditions which all too often have been the subject of a non-analytical approach.

The projects of the Geotechnical Science Laboratories are attractive to graduate students who have had some working experience in a practical field and who understand the benefits of a wider scientific approach. It is, in turn, the relevance of the scientific work to practical problems that has led to the unique opportunities for graduate study. Also indicative of the practical value of experience in the laboratories, is the extent to which members are called upon to act in a private capacity, as consultants or advisors to government and industry.

Laboratories Advisory Board

The Geotechnical Science Laboratories has a distinguished 11-member advisory board made up of seven faculty from the University, and four persons from outside Carleton. The four members appointed by President Beckel to the Geotechnical Science Laboratories Advisory Board, from outside the University are: Fern Hurtubise, Senior Vice-President of Envirocon Ltd., former Vice-President of Forintek and before that Chairman of the Federal Environmental Assessment Review Office; Dr. Charles H. Smith, Charles H. Smith Consultants, former Senior Assistant Deputy Minister, Energy Mines and Resources, Canada; Dr. A. Judge, Earth Physics Branch, Energy, Mines and Resources; and D.W. Hayley, Vice-President EBA Engineering Ltd.

Carleton members of the Advisory Board include: Tom Ryan, Vice-President (Academic); Syd Wise, Dean of Graduate Studies and Research; Dennis Forcese, Dean of the Faculty of Social Sciences; John Moore, Director of the Ottawa-Carleton Geoscience Centre; Patrick Selvadurai, Chairman of the Department of Civil Engineering; Tom Wilkinson, Chairman of the Department of Geography; and Peter Williams, Professor of Geography and Director of the Geotechnical Science Laboratories.

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The French Connection

A Study of the Effects of Frozen Soils on Pipelines

The 1944 landing beaches of Normandy may seem to have little connection with arctic permafrost, but scientific research being conducted there could one day facilitate the construction of major gas pipelines in Canada's frozen north.

Caen, Normandy, is the site of a major three-year study on the effects of frozen soils on pipelines. Carleton's Geotechnical Science Laboratories are collaborating on the project with France's Laboratoire Central des Ponts et Chausées, Centre National de la Recherche Scientifique, and Ecole Nationale des Ponts et Chausées. The study is designed to come up with some fundamental scientific information about how huge pipelines are affected by frost heave.

Director of the Geotechnical Science Laboratories, Peter Williams, author of *The Surface of the Earth: An Introduction to Geotechnical Science*, says that although a great deal of publicity has been given to the environmental, ecological, and social impact of northern pipelines, less has been given to the fact that there are also technical concerns regarding the construction of such megaprojects in the north. Quite simply, he says, we know insufficient about how huge pipelines carrying sub-zero degree gas will behave under the arctic's extreme environmental conditions.

The study is the first examination of the effect of frozen soils on pipelines under controlled conditions. Oil and gas companies have constructed test sections of pipeline in the north, but there are too many variables in nature for these test projects to reveal basic scientific relations, Professor Williams says.

The oil and gas companies and their test projects are like companies doing test flights of new aircraft but needing to know more of the basic mechanics of flight, Professor William says. Researchers in Caen are trying to understand those basic mechanics of pipeline construction in cold places.

In Caen, an 18-metre piece of pipe is buried in a research facility previously used for testing road sections under frost conditions. Cold air, to simulate arctic natural gas, is pumped constantly through the pipe.

Conditions are meticulously controlled. Two types of soil are being used in the experiment, both carefully selected and trucked in from great distance to ensure their absolute purity and uniformity.

Inside the research facility (about 20 metres long, and similar in appearance to a warehouse) climatic conditions can be controlled, as can the temperature of the air being pumped through the pipe. With conditions like these, the causes of deformation of the pipe can be pinpointed far more accurately than with a test project in the north.

Because the research is being conducted inside what is in effect a giant laboratory, it makes no difference that Normandy is not exactly like the Arctic. Temperatures outside may soar, but inside the facility it is a constant zero degrees.

The facility, built to study the effects of freezing on road and railway foundations, became vacant five years ago. Carleton's Geotechnical Science Laboratories had been looking for somewhere to do research on pipelines and permafrost, and when the French facility became available, it seemed a good opportunity. In return, the French gain the benefit of Canadian expertise in the area.

The cost of conducting research at such a distance is more than outweighed by the opportunities it gives Canadians and by the shaved costs prior to having a facility in Canada, Dr. Williams says.

French support for the work arises through scientific interest in thermal problems in soils as well as the international outlook of the French pipeline industry. *Le Monde*, as well as several other French newspapers, has given substantial coverage to the project.

The project has already received $300,000 in funding from the Canadian Department of Energy, Mines and Resources. The figure will probably exceed $500,000 when the study is complete. That may sound like a lot of money, but Dr. Williams describes it as a "small sum in relation to the enormous cost of gas pipelines."

Canadian funds have paid for some of the instrumentation used in the project, some of which was developed in Carleton laboratories, and have also paid for Canadian researchers and graduate students to carry out auxiliary theoretical and laboratory studies in Canada. The French, in turn, have provided the research facility as well as technical staff.

The project has been underway 22 months. In January, 1982, work began on the design and installation of equipment. Soil already in the floor of the facility had to be removed; the drainage tubes, a layer of drainage soil, and several layers of styrofoam, PVC and anticontaminant material installed before it could be filled with 115 centimetres of the two types of soil used in the experiment — one in each half of the floor. Then the pipe, 18 metres long and 1.5 metres in diameter, was installed and surrounded by a bevy of instruments to measure soil and water temperature and pressure, and to gauge possible deformation of the pipe.

Once the installation was complete, the flow of cold air through the pipe was switched on, and ran from September to June, followed by a thawing phase. A second cold phase has recently begun.

Throughout the process, observations and measurements are being done continuously. Four graduate students have already benefited from the unique experience of being sent to the Caen facility for four to five month stints as project managers. A senior French technologist and a French student are also on site taking readings and analyzing data. Data collected at Caen is sent to Carleton on magnetic tape.

As the cold air passes through the pipe it freezes the surrounding soil. Differences in temperature between the different types of soil, water in the soil, and air create stress along the length of the pipe.

Results have been dramatic. Where the pipe passes between the two types of soil, it has been significantly bent. So far, one side of the pipe is about six centimetres higher than the other, an amount that Professor Williams says could have important consequences on a working gas pipeline. That much of a bend in a huge pipeline hundreds of miles long could put dangerous stresses on parts of the pipe, or even cause breaks, Professor Williams says.

Although the interests of researchers on the project are purely scientific, their findings will no doubt some day benefit the oil and gas industry.

For Professor Williams and the other researchers connected with the project, it has provided an unparalleled opportunity to work with other members of the international scientific community.

Researchers in Caen are far from isolated, since the research facility is part of a big research station of the Centre National de Recherche Scientifique (the French equivalent of the National Research Council). Scott Dallimore, the first graduate student from Carleton to work as field project manager, says this exposure to another country's scientists was one of the benefits of the experience.

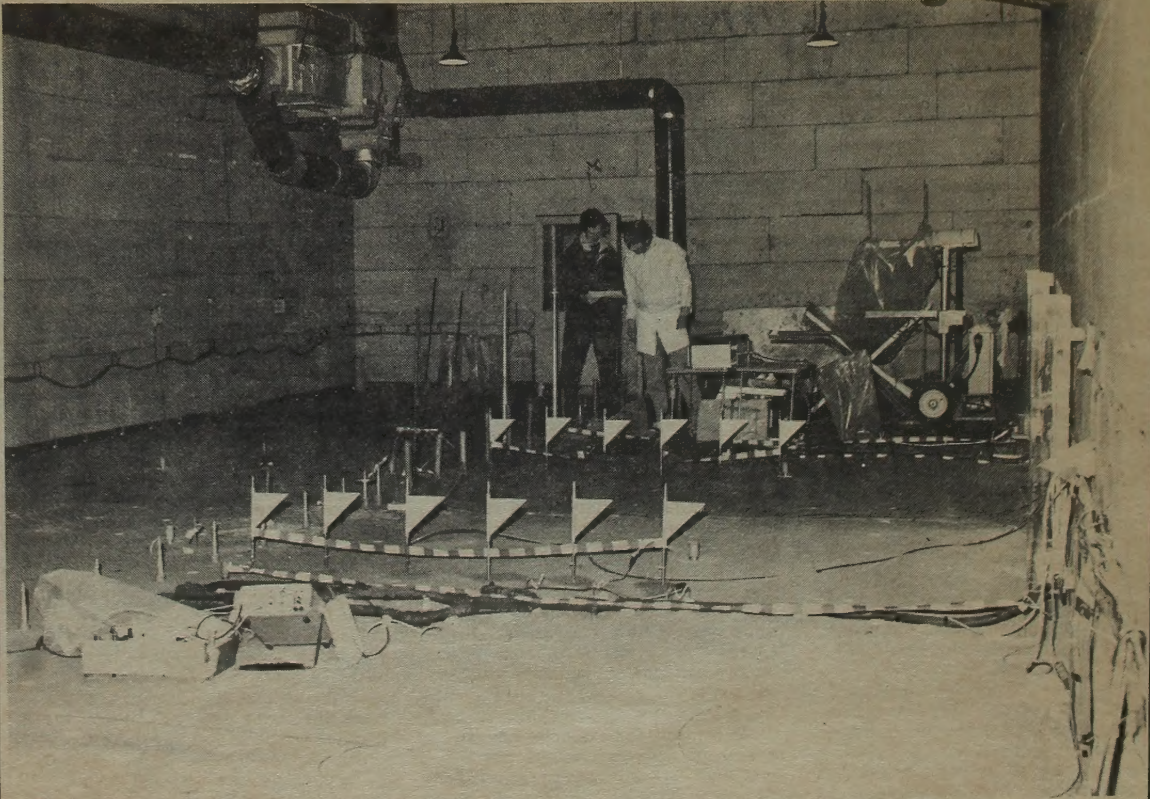
Dr. Williams says the project is also a good example of how universities can put together interdisciplinary teams of experts, something consulting firms cannot do. The Centre d'Ingenierie Nordique of the Ecole Polytechnique in Montreal is doing some of the data analysis for the project. Branko Ladanyi, Director of the centre, is well known for his studies of the mechanical properties of frozen soil.

Field Project Manager Henry Crawford takes precise measurements using an instrument designed by William Bowes for monitoring movements of the buried pipe.

Michel Fremond, Dr. Williams' French counterpart on the project, is a distinguished applied mathematician. Working with him is M.J. Aguirre Puente, a soil physicist with Centre National.

Dr. Williams' particular interest is in thermodynamics of freezing soils, and Professor of Geography Michael Smith, Professor Williams' co-principal investigator, is concerned with thermal analyses.

Professor of Mechanical Engineering William Bowes designed a device which measures the deformation of the pipe. Margo Burgess, a scientific officer with Energy Mines and Resources, was seconded to the project as a graduate student. Gilles Lemaire, a French student, came to Montreal to do graduate work "abroad" and found himself in Caen as a member of the Canadian team. Like geotechnical science, the Caen research project cuts across a variety of fields and disciplines.



Henry Crawford instructs his successor Doug Fisher in the instrumentation above the buried pipe, Caen, France.

Changing Climatic Conditions and the Permafrost

Dramatic evidence of melting permafrost in the Stewart River Valley, Yukon.

The suggestion that the earth's climate is getting warmer due to increased carbon dioxide in the atmosphere may mean little more to most of us than the possibility of slightly more bearable winters. In the north, however, it could have serious consequences. With warmer weather, whole landscapes could disappear, and other areas could become filled with pits and depressions as warmer conditions melt away the permafrost.

Associate Professor of Geography Michael Smith has spent the past two years trying to determine how changing climatic conditions could affect permafrost.

He says scientists know from studying the effects of past changes in climate that polar regions experience much wider swings in temperature than over the rest of the earth. An average global temperature increase of one or two degrees could mean a change of six to 10 degrees in the Arctic.

Professor Smith has been working in the Yukon's Stewart River Valley, studying areas where the permafrost is currently melting in an attempt to find out why it is dong so. When the permafrost does melt, he says, the resulting landscape is called thermokarst, a pitted landscape, full of depressions where mases of ice have melted out of the ground.

From 1880 to 1940, the earth experienced a period of gradual climatic warming, perhaps caused by the beginning of an increase of carbon dioxide in the atmosphere, or by the world-wide lack of volcanic activity during the period. By studying thermokarst dating from this period, Professor Smith hopes to be able to predict the effects of future climatic warming on the permafrost.

His research has two main aims. He wants to find out if a warmer climate does, in fact, cause melting of the permafrost. He also wants to look at the rate of thaw of currently melting areas of permafrost, to see if it is related to climatic conditions.

Professor Smith and graduate student Chris Burn are studying an area of the Stewart River Valley that is filled with thermokarst ponds—lakes formed by water collecting in depressions in the melting permafrost. By examining the rings of trees that fell into these ponds and died when the ponds were formed, Professor Smith has dated the ponds at 100 to 150 years old.

This date corresponds to the recent period of climatic warming, but he says there is also evidence of a forest fire in the area at the same time. Professor Smith plans to examine other regions in the valley to see if there is widespread evidence of permafrost melting dating from the same time. If so, he says, it would indicate that it has been the result of climatic change.

In another facet of the project, graduate student Dan Riseborough is working with Professor Smith to study the effect of the microclimate of the surface of the ground on the underlying permafrost. Professor Smith says vegetation, particularly forest, acts as a buffer that controls the way the climate influences the ground.

Changes in microclimate often explain the fact that in some areas of the Stewart River Valley, permafrost is growing and in others it is melting, Professor Smith says.

Dan Riseborough has been taking readings of air and ground temperature, radiation and evaporation in a forested area of the Stewart River Valley. These readings have been fed into a computer model. Smith and Riseborough, are able to predict how specific changes would affect the rate of permafrost melting.

This ability to predict changes in the permafrost could have important practical applications. Assessment of terrain for building pipelines or roads in the north is a difficult task anyway, and if large areas of permafrost begin to melt because the climate is getting warmer, it would become much harder.

In part of the region Professor Smith is studying, the permafrost contains up to 90 per cent of ice by volume. As this ice melts, the entire landscape is literally flowing away toward the nearest river. At one spot, Professor Smith says, the melted area is 50 feet lower than the adjacent unmelted area.

A pipeline or road built on ground that began to melt in this fashion clearly would not last long. If such changes and the rate at which they will occur can be predicted, suitable precautions could be taken in the construction of roads and pipelines in the north.

This year, Professor Smith had four undergraduate students working in the Stewart River Valley, drilling holes to collect samples of material in the ground, installing electrical thermometers, and taking readings. A local Indian family will continue to take readings throughout winter.

Professor Smith hopes to continue to collect readings for the next 15 to 20 years, adding data to the computer model to make its predictions more accurate.

Michael Smith's research has been funded by a research contract for about $85,000 per year from the Department of Energy, Mines and Resources, from money designated for energy research and development.

Arctic Ground Water: Composition and Effect

To you or me, one sample of water may appear to be just like any other. But give Fred Michel a beaker of the stuff, and he'll be able to tell you its history—where it has been, how long it has been there, and when it last fell from the clouds as rain.

Fred Michel, Assistant Professor of Geology, is well acquainted with water, particularly arctic ground water. Since 1975, when he was working on his Master's degree, he has been travelling to the Arctic for a few weeks each year to drill holes in the ground and remove samples of water or ice.

Telling the history of each water sample is no magic trick—Professor Michel simply counts its isotopes. Isotopes, according to the dictionary, are "any of two or more forms of an element having the same or very closely related properties and the same atomic number but different atomic weights." As Professor Michel explains it, isotopes are individual atoms of an element which have different weights.

Professor Michel uses two hydrogen and two oxygen stable isotopes in his research. All are present in every water sample, but depending on what has happened to that sample in the past there are different concentrations of different isotopes. For example, when water evaporates from the ocean, most of the heavier isotopes are left behind, and the colder that water vapor gets, the fewer heavy isotopes it contains.

Water in polar regions has a very low count of heavy isotopes. Precipitation that fell during a particularly cold spell, like a glacial period, has a particularly low count, and conversely, rain that fell during a warmer period has a higher count.

By drilling through an ice mass that has existed for thousands of years, scientists like Professor Michel can come up with an accurate record of climatic conditions over the centuries. Each layer of ice will bear the evidence, in isotopes, of the temperature when that water fell as rain or snow. Studies in Greenland, both polar regions, and the Yukon have used the isotopic composition of snow and ice to develop climatic records. Unfortunately, such studies are limited to areas where glaciers still contain snow or ice from several thousand years ago.

Professor Michel has set himself a more difficult task. He is interested in the climatic records of areas without glaciers. To come up with these records, he studies ground water. In much the same way that other scientists drill through snow and ice, Fred Michel drills into the Arctic ground, through layers of ground ice.

If variations in isotopic composition exist in these layers, he knows the ground water has not moved very much in centuries, and he can use the isotopic information to reveal a climatic history of the area. If there is ground water movement, there won't be the same variations in isotopic composition, but Professor Michel can still study the water's isotopes to learn something about the pattern of ground water flow in the area.

He can tell, for example, how recently the water fell as precipitation and that in turn will tell him something about where the ground water flow originated. He can pinpoint the location of springs and document changes in the permafrost level.

All these findings have a number of potential applications, particularly with regard to the construction of pipelines or roadways. Such construction projects often disrupt the flow of ground water. In the north, this could lead to the build-up of ice masses so huge they could eventually bulldoze right through a road or pipeline. Chilled gas pipelines will draw water toward them, and if there is a large pool of underground water adjacent to a pipeline it increases the chances of frost heave and damage to the pipeline.

Knowing where ground water discharges in springs is important for wildlife and fish that need open water. Altering water flow systems by pipeline or road construction can change or destroy natural habitats.

From a purely academic point of view, Fred Michel says his research is helping scientists to understand phenomena like frost blisters in the permafrost, or pingos, hills of ice and soil 50 or more metres in height.

This summer, he began a new project—the study of underground ice masses from three to 10 metres thick. By studying the isotopic composition of such masses, he hopes to learn how they were formed. There are several theories. One is that such masses are leftover bits of glaciers. Another is that they are sections of ice wedges, cracks in the ground that have filled with water which has subsequently frozen. A third theory suggests that the masses are composed of ground water which has been drawn toward a frozen section of soil.

If we know how such masses were formed, Professor Michel says, we will know if it is safe to put pipelines through them. Glacial ice, for example, could be melted out, with assurance that the surrounding ground would become stable. New ice, on the other hand, would indicate that there is some water flow, and that even if it were melted out, more ice could accumulate.

One of the isotopes Fred Michel uses in his research is tritium, a radioactive isotope of hydrogen. The testing of nuclear bombs produces tritium as a by-product. The presence of tritium in water is measured in Tritium Units (T.U.'s). One T.U. is the equivalent of one atom of tritium in 10^{18} atoms of hydrogen. The natural occurrence of tritium is five to 20 T.U.'s.

Since nuclear testing started, the highest occurrence of tritium in rain water in the Ottawa area was 10,000 T.U.'s in 1963. There is nothing dangerous about that level, Professor Michel says. In fact, it could get several thousand times higher without adversely affecting us. However, the level of tririum in water does provide scientists with a valuable indication of when ground water fell as rain. Because of the sharp increase since nuclear testing began, it is possible to say accurately whether the water fell as rain before 1953, between 1953 and 1963, or post 1963.

This ability to date relatively recently-fallen rain allows Professor Michel to gauge the aggradation, or moving upwards, on the permafrost table, and to judge the rate of infiltration of water into the permafrost.

Valuable Assistance from Geography's Science Workshop

Most of the projects carried out by professors and students affiliated with Geotechnical Science Laboratories either would not be possible or would be a lot more expensive if it were not for Laurent Boyle.

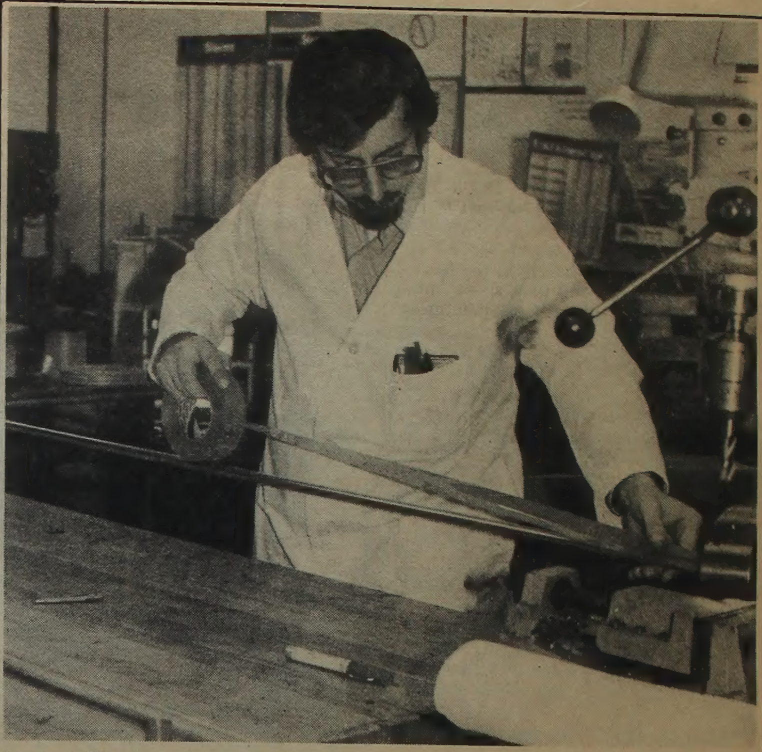
Mr. Boyle is the technician in the Geotechnical Science Workshop. For the past eight years, he has designed and built most of the special instruments and apparatus needed by Carleton's geotechnical scientists.

He has made an instrument for collecting samples of the frozen bed of the Bering Sea; a wave machine; an ice microtome for shaving samples of ice thin enough for study under a special video-recording microscope; and a microscope for measuring tree rings to within 1/1000th of an inch.

Many of the projects Mr. Boyle works on are rush jobs. Students generally have only an eight-month academic year to plan, carry out, and report on a project, and they cannot afford to wait weeks or months while a special piece of apparatus is being designed and built. Mr. Boyle says they can get things done faster and cheaper at the Geotechnical Science Workshop than they could anywhere else. He works many evenings and weekends to get things done on time.

Alan Pendlington, supervisor of the workshop and the Geotechnical Science Laboratories, says students have first priority in the workshop. A student with a project to be done has never been turned away. The workshop has a budget from the Department of Geography of $2,500 per year for materials and the upkeep of machines.

Most of the projects designed and built in the workshop are paid for by research contracts. Budget money goes toward projects for students who have no funding, and that money is stretched even further by the judicious use of materials left over from funded projects. Entire projects have been built in the workshop from bits and pieces of material from the left-over bin, Mr. Boyle says.



Laurent Boyle at work on a geotechnical science project in the workshop, Loeb Building, Carleton.

Alumni in the Field

Most graduates with masters or doctorates in the geotechnical science field subsequently obtain positions relating to their studies. For example, Jerry Chyurlia (1970) is a soil and hydrological survey specialist, and a sessional lecturer at Carleton; Bill Nickling (1972) is an Associate Professor at Guelph University specializing in soil erosion; Marsha Shepherd (1973) is with Atomic Energy of Canada; Arve Tvede (1977) is with the Norwegian State Water and Electricity Resources Board. A strong Calgary contingent includes graduates who work for Petro-Canada, Northern Pipeline Agency, various consulting companies, and an environmental law practice. Many also work in scientific branches of the provincial and federal governments.

Thermal Properties of Frozen Soils

In the temperature range just below 0°C, the thermal properties of soils change significantly with small changes in temperature. That is because soils at temperatures below 0°C contain both ice and water, the relative proportions depending on the temperature. The usual methods of determining soil thermal properties are not feasible, since they depend on prolonged heating of the soil sample, which will cause a change in the proportions of ice and water, and thus a change in the properties being measured.

Unfortunately, for many studies of the ground thermal regime, especially where frost heave or thaw settlement is of interest, it is precisely the temperature range close to 0°C which is of concern.

Michael Smith and Dan Riseborough a graduate student in the department, have developed a technique, based on transient heat flow from a copper probe, which enables the determination of the thermal properties of frozen soils in the temperatures range 0°C to -2°C, and beyond. A small input of heat to the probe and a very sensitive temperature measurement system (+0.001°C) keep the temperature change in the test sample very small.

This work has been supported by a grant from the Natural Sciences and Engineering Research Council (NSERC).

Research and Scholarly Activity

Behaviour of Permafrost

Ice-bonded permafrost is found extensively beneath the floor of the Beaufort Sea, and its presence requires special attention in offshore engineering. To predict reliably the behaviour of permafrost for engineering purposes, accurate data on the volumes of ice and water are required. This phase composition must be determined by direct measurements on core samples, carried out immediately upon recovery.

Dan Patterson, Research Associate in the department, and Michael Smith have developed a suitable field technique, using time domain reflectometry, to determine the dielectric property of the soil, which varies in a known way with the water content. Various difficulties due to the high salinity of seabed materials, had to be overcome. Until this development there was no suitable technique available. It has since been used by federal government scientists, and by some of the major resource companies in their offshore geotechnical programs in Canada and Alaska.

The basic research work has been supported by research contracts with the Department of Energy, Mines and Resources, and a research grant from NSERC.

Wide Distribution of Publications

Publications, Reports and Theses in Geotechnical Science, the annual listing of documents from the Geotechnical Science Laboratories, is sent to more than 300 recipients annually, spread through 12 countries. Over 150 items from the list are requested yearly, and these are generally supplied at cost. Exchange arrangements have been established with many countries so that subscriptions to journals and many occasional publications are received in the Laboratories at Carleton.

Landslide Research

Although it is natural that Canada's cold climate stimulates much of the Geotechnical Science research, there are other "Canadian" problems of which landslides in the Leda clay are one. These clays are abundant in the Ottawa and St. Lawrence areas and can cause considerable loss of life or property damage as in the case in the St. Jean Vianney slide in Quebec in 1971. Associate Professor of Geography J.K. Torrance is making studies of the physical and chemical factors which result in the clays becoming unstable and "landsliding" after thousands of years in position. He looks particularly at the chemical elements in the water of the soils and the nature of clay particles. Using a coaxial viscometer, a special help in investigating the clay strength, he is currently studying the big landslide that occurred near Casselman, Ontario several years ago. Paul Conlon of the department, recently completed his Ph.D. on changes that take place over long periods in such clays.

Professor Torrance's work also extends to studies of soils in warm climates and he is currently spending a sabbatical leave at the tropical soil research program, North Carolina State University. He has also contributed to research reports on soils from Saudi Arabia.

Seminars Offered

The Geotechnical Science Laboratories offer a variety of seminars for academics, professional engineers and government officials interested in the practical aspects of the geotechnical sciences.

Several seminars have been offered jointly by Carleton and France's Ecole Nationale des Ponts et Chausées, including one on soil freezing and highway construction offered both in Ottawa and Paris. A second, on pipelines and permafrost, was designed to inform government and oil company executives about the implications of cold climates on pipeline construction.

The seminars have been attended by academics from several countries, oil company executives, and senior representatives of federal regulatory agencies in Canada, France, and the United States. The next one, on freezing of soil around pipelines, is planned for February, at the Caen test facility.

Wetlands Evaluation System - Hydrology

T.P. Wilkinson was under contract in 1982 and 1983 with the Ontario Ministry of National Resources, and Environment Canada (Canadian Wildlife Service) to evaluate procedures for assessing surface water components in wetlands in Southern Ontario. The surface hydrology condition of and around wetlands is seen as only one of some 43 dimensions used for assessing the value of wetlands. The overall aim of the project is to provide guidance for planners and conservationists on the intrinsic value of any specific wetland for preservation or development. The scheme was field tested by OMNR/CWS in summer, 1982. With modifications developed over the winter, the wetland survey was underway by the summer of 1983. A number of Carleton students in biology and geography were employed as surveyors.

Visiting Scientists

Each year the Geotechnical Science Laboratories are home to distinguished visiting scientists who contribute to the undergraduate program in the Department of Geography.

Dr. Bengt Erik Ryden from the Division of Hydrology, University of Uppsala Sweden, spent last year at Carleton. He also took part in fieldwork in the Yukon. Currently, Dr. Donald Davidson of the University of Strathclyde, a specialist in soils and land use, is with the laboratories. Next term Dr. Roger Kettle, from Aston, Birmingham, U.K., a civil engineer and consultant specializing in low temperature problems, will be assisting in pipeline frozen ground studies. These scientists are attracted by common interests, and contract research can provide some financial support.

Visitors come from Ottawa and other parts of Canada, and from many countries especially Scandinavia which has similar cold climatic conditions.